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Continued as the Journal of Electricity, Power and Gas.

SAN FRANCISCO, CAL.

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The JOURNAL OF ELECTRICITY

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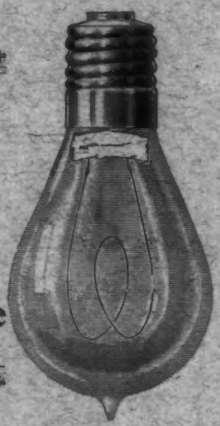

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THE JOURNAL OF ELECTRICITY.

VOLUME VII. SAN FRANCISCO, JANUARY, 1899. NUMBER 1.

Water Powers in Southern California.

BY C. G. BALDWIN.

The history of water-powers in southern California has been short, somewhat extensive, and in general, unsatisfactory. In view of these facts and of the further fact that other undeveloped powers remain, and are being industriously promoted, a comprehensive statement of all the essential considerations which relate to such enterprises seems eminently proper, and this brief discussion is written by one who has had the valuable experience of disappointment. He has learned some things from failure. The following pages are for the benefit of those who own stock or bonds of such companies or who contemplate such investments. The aim is to make the layman intelligent upon the subject so that he may be in a position to use experts rather than be helplessly dependent upon them. The suggestions and information herein contained would have saved several men in southern California many thousands of dollars of bad investments made within the last few years. Gentlemen have confessed to me that they relied unintelligently and helplessly upon the engineers of promotors.—C. G. B.

I.—CAUSES OF DISAPPOINTMENT.

IN all cases the main, and substantially the only difficulty, has been shortage of water. Companies have based their expectations upon far more than the lowest water they have had during dry seasons.

The first plant built in southern California, using a high potential and long distance transmission, was that of the San Antonio Light and Power Company, of Pomona. Indeed, no commercial plant anywhere had, up to that time, used over a 4000-volt current or transmitted over fourteen miles, while this plant boldly attempted a thirty-mile transmission and a 10,000-volt current. Electrically it was far more successful than the highest hope of the Westingnouse company, which made the installation. It is due to Mr. William Stanley, of the Stanley Electric Manufacturing Company, of Pittsfield, Mass., to say that he approved the plan which I presented to him and agreed to install the plant if the Westinghouse company and the Thomson-Houston company refused to do so. This proposition of Mr. Stanley's led both companies to reconsider their refusal to undertake it and the plant was put in under the direction of Mr. L. B. Stillwell, now of the Niagara plant. From the beginning, one man on duty in the mountains regulated the incandescent lamps of San Bernardino thirty miles away so perfectly as to compete on equal terms with the local steam plant, and at the same time he controlled the arc lights and incandescents of Pomona, thirteen miles in the other direction. The line insulation was wholly satisfactory in all weathers. The cost of installation conformed very closely to estimates made, and the current expenses proved considerably less than had been forecast. Thus a satisfactory beginning was made. Prices for lights, though low—$8.00 for arc lights and 50 cents to 80 cents per incandescent lamp per month—showed a good profit and the business grew. The enterprise has proved, however, quite disappointing to stockholders. The estimate for water was placed at 1000 miners inches, or 9000 gallons per minute. The record of the preceding seven years showed the lowest water of no year less than 700 miners inches, and the very lowest water of one year was over 1200 miners inches. The enterprise was built upon 1000 miners inches and a fall of 400 feet. This would furnish about 900 horse-power gross, and deliver for use about 600 horse-power. At a cost of less than $150,000 and with a current expense of less than $450 per month, this would furnish a good income. But alas for our hopes! The water dropped as low as 230 miners inches two years ago and considerably lower this lowest year! A steam plant added to the investment, and fuel expenses have eaten up profits. Having "promoted" this enterprise, I know the facts to my sorrow. Experience goes to show that the safe way to estimate your product and your business is with some distinct reference to the output of lowest water in very low years, if not the lowest year. During the last five years the water has run much below one-half our estimate of 1000 miners inches.

The most successful water power in southern California thus far in operation* is the one located on Mill Creek about two miles below its mouth, and about seven miles from Redlands—the Redlands Light and Power Company. Their fall is 510 feet and the very lowest water this year was just about 400 miners inches. The three-phase system has permitted a perfect motor service. Their business has been large and productive. The use of oil has cut a large figure this year, however, and has proved a great disappointment to those who depended upon them. The company had made large contracts at very low prices—not much more, in some cases, than one-half the cost of fuel at their power house. In spite of this experience the writer believes, and has good grounds for the belief, that an inside view of the books of the Redlands company will show a very fair investment, and its plans to increase its output to meet its demands are definite and entirely feasible. Its stock has paid dividends and is at par. Its patrons must be patient and suffer shortage and inconven-

* This was written before the transmission of the Southern California Power Company began operations.—ED.

ience in a dry year in return for the large advantages heretofore enjoyed and likely to be enjoyed with greater certainty hereafter. Here again the low water and nothing else was the cause of loss.

The latest electric transmission plant that has been placed in operation has suffered the greatest disappointment, being able to deliver less than 200 horse-power this summer on a large investment of capital. With the most perfect machinery and no unfortunate experience in unexpected cost of their hydraulic work, the disappointment lay wholly in the amount of water. Many undeveloped plants will never be developed because the series of dry years, and this dryest year in the last nineteen, have shown that they cannot produce an amount of power which will justify the investment.

II.—FOUR VITAL QUESTIONS.

There are four vital questions to be asked in the case of every water-power, and only four.

How much water at lowest? How much fall? Cost of development per horse-power? Market for power? We will discuss them in order.

In fixing the proper estimate of the water, it is exceedingly desirable to know the very lowest record. This it is oftentimes difficult to get. Traditional stories of dry creek beds, from the oldest inhabitant, are not satisfactory. It is one of the advantages of the past six years of comparatively dry weather that we can get at pretty exact figures from the weirs of the irrigating companies, and every layman should know how to measure a weir himself. It is unwise to trust the answers which inquirers receive from interested parties. Sometimes the weir will be purposely constructed to deceive, a very easy matter if a stake, driven in the water behind the weir, is depended on. Not infrequently the person who gives you the information does not know how to figure out the amount and is himself deceived. Often he is instructed to tell no one. The reputation of a water system may suffer from too exact knowledge as to lowest water. I was lately informed that a stream which I had measured as 525 miners inches was "about 800 miners inches." That word "about" covers a wide area with many men. Engineers are not all reliable. A gentleman brought me a report of an engineer upon a stream with which I was somewhat familiar, showing about 3000 miners inches on a certain day in October, of a very dry year. I knew that the lowest water that year was far below 500 miners inches, and concluded that the engineer must have taken his measurements immediately after a storm. On looking up the records of rains I found that such was the case! You must know your engineer in the case of a water-power and be no more trustful than in the examination of a gold mine. Our hard experiences justify the utmost care in finding out the water supply. A weir can be set in small streams in a few minutes, or at most a few hours, and its measurement will limit the word "about" to a very narrow area. With a cut in a board six inches deep and four feet wide (the edges beveled carefully on the side down stream so as to furnish no surface to retard the water in passing over) you can measure over 200 miners inches; for larger amounts make the cut wider and deeper.

The footnote* gives table showing the number of miners inches which each fraction of an inch in depth over the weir will give, and illustrates its working. The only thing left is to determine the depth. If you rely upon a stake set back of the weir about two feet and a little to one side in quiet water, you must determine that the top of this stake is on a level with the bottom of the weir and that the bottom is level. Then with dust upon a small stick it will be easy to measure the distance from top of stake to the surface of the water, the dust line showing how far the water rises. A method which permits you to easily correct your weir, if not set level, and saves driving and leveling the stake is as follows: Take a stick about 1½ inches square and 2½ feet long, straight edge on one side; put in a leg long enough to bring this straight edge above the water when the bottom of the leg rests on the bottom of the cut in the weir. Put in another leg at the other end, dip it in water and cover with dry dust. Now put your pocket level on the straight edge; hold the bottom of the leg at one corner of the weir and slowly lower the dusted leg into the still water back of the weir about two feet. When the bubble strikes the level, remove it and subtract the distance from the dust line to top of straight edge from the length of the leg on the weir measured to the back of the straight edge also. This will give the depth of water over the weir at that corner. Do the same at the other corner and take the half of the sum of the measurements. Thus you correct the error of the weir and save the setting of the stake, no easy matter without two men and a surveyor's level and rod. Be careful that the water flows smoothly over the weir from comparatively quiet water; if necessary, dig out a settling pond above the weir.

Having found the measurement of a stream in the middle of August, 1898, before any rains, and making the measurement yourself, or having it made by an engineer employed by yourself, you have taken the first and most important step, and in many instances this at once settles the question adversely. Streams reported to be "about 700 inches" have been found to measure only 125

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* Weir measurement expressed in miners inches for each inch in width:

Depth in in.		⅛	¼	⅜	½	⅝	¾	⅞
1	.33	.39	.46	.53	.61	.69	.77	.85
2	.94	1.03	1.12	1.22	1.32	1.42	1.52	1.63
3	1.74	1.85	1.96	2.07	2.18	2.30	2.42	2.54
4	2.66	2.79	2.92	3.05	3.18	3.31	3.45	3.59
5	3.73	3.87	4.01	4.15	4.30	4.45	4.60	4.75
6	4.90	5.05	5.20	5.36	5.52	5.68	5.84	6.00
7	6.16	6.33	6.49	6.66	6.83	7.00	7.19	7.34
8	7.52	7.70	7.88	8.06	8.25	8.44	8.63	8.82

An example worked by this table would be as follows:

Weir 48 inches wide, water over weir at one corner 3⅛ inches; at the other 4½ inches; how many miners inches are flowing over the weir?

Method: 4½+3⅜÷2=3$\frac{13}{16}$ inches average depth. By table I find 3⅝ gives 2.30 miners inches, and 3¾ gives 2.42 miners inches, half way between gives 3$\frac{13}{16}$ as 2.36 miners inches. Multiply this by 48 and you have 113.28 miners inches, the true result.

inches this dry year. Streams "as big as a man's body and very swift" I have found to be actually pools of water from which the real flow was only one or two miners inches. Photographs are of no value. In some way you must get actual and reliable measurements of the number of gallons per minute. One miners inch is nine gallons per minute.

The next vital point is the fall obtainable. These range in southern California, in plants now in, or projected, from about 400 to 2200 feet, and you do not need to depend upon an engineer to tell you what power the fall will produce. It is simply the weight of the water; one gallon weighs 8⅓ pounds, 100 miners inches or 900 gallons weigh 7500 pounds; if this moves 400 feet it is equal to 400×7500 pounds moving one foot in a minute, or 3,000,000 pounds. One horse-power moves 33,000 pounds one foot in a minute; therefore, 100 miners inches falling 400 feet will produce as many horse-power as 33,000 is contained in 3,000,000—90.9 horse-power. In other words multiply the water expressed in miners inches by 9 to reduce to gallons, by 8⅓ to pounds, and this amount by the fall in feet and divide by 33,000, and you have the theoretical horse-power. If this is to be used at a distance of ten to one hundred miles you must take away about one-third for losses. These will be as follows: Not less than 15 per cent. on water wheel, 5 per cent. of the balance in generator; 4 per cent. of the balance in "step-up" transformers; 4 per cent. to 10 per cent. line loss, depending on size of copper wire; 4 per cent. again in "step down" transformers, and 3 per cent. to 5 per cent. in distribution losses. In general, we say, count upon 66 per cent. of the weight of your water for actual use at the end of the wires. A fall of 2200 feet is entirely safe. Much above that head, it would be necessary to divide the fall and multiply the power houses. This means greater initial cost and greater current expense.

An inch of water falling 400 feet is worth for power just one-fifth as much as an inch falling 2000 feet. The fall is thus of great importance and can be quickly determined by your own engineer, or if it is a considerable fall an aneroid in your own hands will be accurate enough if the ground is traversed twice to correct any error caused by change of barometric pressure in the time the ground is traversed. Thus a day's time will determine the quantity of water and fall with sufficient accuracy to form a general basis of estimate of values. Such a trip would have saved many thousands of dollars in many cases of actual experience. Plans to use 2000 miners inches would not be made when half the year showed less than five hundred. You cannot guess water with sufficient accuracy nor elevation either. You need to know.

Now as to cost: There are all sorts of propositions. In some the hydraulic work will amount to $1000 for every horse-power you can deliver in a low year. Such a plant is worthless. In others, the cost will be perhaps as low as $30. Such a plant, other things being equal, is of great value.

The cost of a plant can be closely estimated. Enterprises such as the San Gabriel, the Southern California Power Company, operating in Santa Ana Canyon, the Redlands Light and Power Company, and the San Antonio Light and Power Company, of Pomona, have given experience from which most, if not all, of the elements needed can be accurately estimated. Elements of uncertainty lie mainly in tunnels. In estimating these, liberal allowance must be made for unforseen conditions of quick sand, very hard rock, etc. There is no excuse for any large error in estimates at this late date. Such errors are sometimes made purposely to encourage the beginning of work with insufficient capital with the hope, on the part of promoters, that once in, the capitalists will finish the plant to save their investment! This can always be avoided, and should be by insisting that before you invest, an engineer of reputation examine all the facts on behalf of the investors at their expense if report justifies the figures of the promotors, otherwise the promotors to pay the expenses. Another way is to ask some responsible financial institution to have its trusted experts make a report upon it upon same condition as to expense. All honest projects are willing to be investigated and court the light. All others should be exposed. With the bitter experiences of failure in this line, and after our dry years, the chances of deceiving an expert as to the merit of a project in which he has no financial or other interest are very remote.

No water power in southern California should cost for the hydraulic work, including power house and water wheels, over $250 per horse-power gross, and expect to make a profit against fuel-oil in most locations. If the hydraulic work exceeds $200 horse-power gross, it should be carefully considered; and by this I mean the amount of water being figured not over 70 per cent. more than in August, 1898. This is far lower than the lowest water of the average year, but it is none too low, for these dry years will come occasionally.

Assume water to be 170 per cent. of the lowest record of 1898, and then ascertain that the cost of your complete hydraulic work will be less than $200 per horse-power, theoretical, as shown by the weight of the water, or else raise a sharp question mark, for there are plants in southern California which, reckoned upon this plan, will run as low as $60 for complete hydraulic work, and while it is very unlikely that all the power needed can be furnished from southern California water powers, still a competitor can dictate terms and force a combination or a surrender, and with a margin of $140 per horse-power he has a great advantage. The cost of a delivered horse-power, net, reckoning water as above, should in no case exceed $400, and such a water power would be of doubtful value since less than $225 will deliver a horse-power net in some extensive plants.

We now come to the fourth and last element, the matter of market:

A water power should seek a market which is flexible as possible so that it may utilize somewhat more than the product of the lowest months in the lowest years. I doubt whether any service but that to mines can be made to pay unless full power installed is furnished for at least

eight months in the year. No market should be sought, therefore, which cannot be supplied in nine years out of ten for at least eight months. It will not pay to install wheels and generators and distribution lines for more than this. In a rough way I would say that not over three times the lowest water of 1898 in any stream should be counted upon for any use at all. I know, however, that practice has been far less conservative, sometimes installing as many as eight times the actual highest production of August, 1898. Such a plan makes great duplicate plants necessary, and this makes competition of oil a very serious danger. Conditions must be very exceptional which justify eight times the lowest product of 1898. I would not today advise more than twice the installation which could be operated at lowest water this year, though this is rather extreme conservatism, especially if any considerable part of the business can be flexible.

In case of mines, the power company can afford to furnish at so low a price, compared with its cost by other methods, that it would be possible to furnish it for eight months in the year, and in one year in five, perhaps not over six months. Mines in southern California are paying from $14 to $22 per effective horse-power delivered to the shaft of their machinery. This can be furnished at so low a price as to secure the whole mining trade, especially if motors are furnished by the power company. Under these conditions there could be a distinct contract to withdraw with sixty days notice, and a water company can make close estimates sixty days ahead on falling water. Street car business and electric lighting, independent of steam duplicate plants, are not satisfactory for a water power unless they together aggregate but one-half of a full load, and the other half is of a kind to be cut down or cut off.

Pumping water for irrigation is good if conditions are favorable. Such users can be cut down somewhat as they can plan for a dry year and short water except in the case of a certain amount for permanent orchards. In case of some slight shortage, their system is still better than storage and free flowing waters which drop to one-half or one-third the average in such a year as 1898 has been. Thus a pumping system of irrigation, based upon twice the lowest water of this year, would suffer less than the other ordinary systems have suffered. This is still more true if such a system does not need to accomodate itself to the full shortage by reason of cutting off of mines and factories before their supply is cut down below a certain percentage. This should be agreed upon. Perhaps the very best field is the mining field alone. The high price of fuel there will always be high. Water powers near these fields can be developed upon lines less conservative than those enumerated above.

III.—COST OF POWER IN SOUTHERN CALIFORNIA.

To determine whether a water-power can secure a market at remunerative rates it is necessary to know what power costs the consumer; for unless the water power can furnish the power at a lower cost it cannot hope to succeed. It must supplant steam and gas engines, overcoming inertia by the force of financial inducements.

Counting fuel oil at $1.00 per barrel, large condensing engines can, under a steady load, produce power at the rate of $60 per annum, twenty-four hours' service. This can only be done in units large enough to nearly eliminate the labor item—not less than 2000 horse-power. A compound condensing engine of 200 horse-power capaclty is running under such conditions as to produce power at the rate of $70 per horse-power for fuel and labor. This is the best small power plant I have found. Steam plants of 20 horse-power cost in no case less than $140 per annum per horse-power for fuel and labor. Gasoline plants of like capacity not less than $200. Distillate plants of 20 horse-power will require not less than $175 per horse-power in fuel and labor. It is not unusual to find a 10 horse-power plant costing $260 per horse-power. The most accurately reported power of this description, rated at 12 horse-power, has cost $217 per rated horse-power, probably $325 per actual horse-power, counting the year 280 days. The most reliable dealers in gasoline engines give two cents per hour per horse-power as the lowest rate which can be safely counted upon for fuel, and 1½ cents for distillate, gasoline being 12 cents per gallon and distillate 10 cents. Inquiry among users confirms these figures, though in many cases a larger cost is found and no well authenticated case of a lower cost. Labor is rarely found to cost less than $75 per month for 24-hour service with gasoline engines, and this is too low for long continued service. A few have operated for a short time with still cheaper labor. Using these elements it is easy to discover the cost of operating small plants.

To make a comparison on a larger scale: Assume two plants, one steam and the other hydraulic, used to distribute power over an area requiring 25 miles for distributing lines from the center of operation of the steam plant, and the water power 25 miles distant from such center, each capable of delivering 1200 horse-power to the motors used to pump water. Allow $1.50 per barrel for fuel oil delivered to the plant. With these assumptions the following table shows comparison between the two plants:

ORIGINAL COST.

	Steam.	Water Power.
Cost of Plant	$ 60,000	$130,000
Generators	27,000	32,000
Lines	12,500	38,000
Motors and Pumps	75,000	75,000
Total cost	$174,500	$275,000

ANNUAL EXPENSES.

	Steam.	Water Power.
Labor and Fuel	$113,000	$ 8,000
Interest and Depreciation	17,450	27,500
Total expense	$130,450	$ 35,500
Expense per horse-power	$108.71	$29.58

It is easy to see that at $108.71 per horse-power, such a steam plant will supplant all isolated plants of 20 horse-power or less, assuming electric motors requiring little attention with constant load and unvarying conditions.

Transmission

RAINFALL AT SAN FRANCISCO FROM 1849 TO 1898.*

BY MARSDEN MANSON, C. E., PH. D.

THE importance of the accurate recording of rainfall at numerous stations is becoming greater each year. This growing importance is due to the greater interests at stake, and to the increasing value of flood waters for diversion and storage; so that not only are these records valuable over agricultural and pasture lands, but over mountain areas. The conditions which control the rate of run-off from these areas are also vital, for upon this rate depends the damage by flood and the value of drainage water for industrial purposes. If the drainage area be stripped of trees and vegetation, and denuded of humus and soil, the rate of run-off is increased, the valleys below are subjected to floods of greater violence, and the streams dry up earlier in the season. A careful analysis of the rainfall of any part of California yields interesting and valuable results. To the farmer these studies are of incalculable value. To the capitalist they serve as guides in his investments in many industrial developments. To the civil engineer they form the basis of study for municipal and irrigation water supply, the dimensions and capacities of reservoirs and conduits, and of the intricate problems of drainage and utilization of waste waters.

The characteristic winter storms in the vicinity of San Francisco commence with a strong southeast breeze. During the progress of the storm the wind shifts to the south, southwest, and west or northwest. The barometer falls during the first and rises during the latter part of these wind changes. These phenomena mark the approach of an area of low barometric pressure from the northwest, and its passage eastward along a line north of San Francisco. These are the general features accompanying the rainfall of ordinary winters. The rainfall frequently extends as far south as 32° N., at which latitude it is from one-half to one-third that at San Francisco.

During summer the phenomena accompanying our winter rains decrease in extent, and retreat northerly some ten or twelve degrees, and California is south of the precipitation caused by the passage of an area of low pressure.

In certain winters, like that of 1876-7, or the one just passed, the character of the storms changes entirely. The change is radical, the phenomena are variable, and more like those accompanying the mild summer rains of Oregon and Washington.

It appears from a general study† of the subject that this difference in the character of the season is due to a shifting of the lines along which the areas of low pressure move to a more northerly route, or to a more restricted area of rainfall as the low approaches the coast and passes into the interior of the continent.

It also appears that the wet winters of California are due to conditions which cause these low areas to move on more southerly lines, and the areas of rainfall to have a correspondingly greater southerly extension.

In order to bring out the extent of these variations in winter rainfall the entire period of observation will be reviewed.

The rainfall at San Francisco has been quite accurately and continuously recorded since 1849. Up to 1870 the record was kept only by Mr. Thos. Tennent. Since that date it has also been kept by the United States Signal Service, and by the Weather Bureau.

The following table gives the monthly and annual rainfall, the totals and means from 1849 to 1898:

Table of monthly rainfall at San Francisco, Cal., 1849-1898, showing mean, monthly, seasonal and yearly rainfall for 49 years:

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Total.
													Inches
1849-50	0.00	3.14	8.66	6.20	8.34	1.77	4.53	4.46	0.00	0.00	0.00	0.00	33.10
50-51	0.33	0.00	0.92	1.05	0.92	0.54	1.94	1.23	0.67	0.00	0.00	0.00	7.40
51-2	1.03	0.21	2.12	7.10	0.58	0.14	6.68	0.26	0.32	0.00	0.00	0.00	18.14
52-3	0.00	0.80	5.31	13.20	3.92	1.42	4.86	5.37	0.38	0.00	0.00	0.04	35.30
53-4	0.46	0.12	2.28	2.32	3.88	8.04	3.51	3.12	0.02	0.08	0.00	0.01	23.84
54-5	0.15	2.41	0.34	0.81	3.67	4.77	4.64	5.00	1.88	0.00	0.00	0.00	23.67
55-6	0.00	0.00	0.67	5.76	9.40	0.50	1.60	2.94	0.76	0.03	0.02	0.00	21.68
56-7	0.07	0.45	2.79	3.75	2.45	8.59	1.62	0.00	0.10	0.12	0.00	0.05	19.99
57-8	0.00	0.93	3.01	4.14	4.36	1.83	5.55	1.55	0.34	0.05	0.05	0.16	21.97
58-9	0.00	2.74	0.69	6.14	1.28	6.32	3.02	0.27	1.55	0.00	0.00	0.02	22.03
59-60	0.03	0.05	7.28	1.57	1.64	1.60	3.99	3.14	2.80	0.09	0.21	0.00	22.46
60-1	0.00	0.91	0.58	6.16	2.47	3.72	4.08	0.51	1.00	1.08	0.00	0.00	19.51
61-2	0.02	0.00	4.10	9.54	24.36	7.53	2.20	0.73	0.74	0.05	0.00	0.00	49.27
62-3	0.00	0.40	0.15	2.35	3.63	3.19	2.06	1.61	0.23	0.00	0.00	0.00	13.62
63-4	0.03	0.00	2.55	1.80	1.83	0.00	1.52	1.57	0.78	0.00	0.00	0.21	10.29
64-5	0.01	0.13	6.00	8.91	5.14	1.34	0.74	0.94	0.63	0.00	0000	0.00	24.52
65-6	0.24	0.26	4.19	0.58	10.88	2.12	3.04	0.12	1.40	0.04	0.00	0.00	22.93
66-7	0.11	0.00	3.35	15.16	5.16	7.20	1.58	2.36	0.00	0.00	0.00	0.00	34.92
67-8	0.04	0.20	3.41	10.69	9.50	6.13	6.30	2.31	0.03	0.23	0.00	0.00	38.84
68-9	0.00	0.15	1.18	4.34	6.35	3.90	3.14	2.19	0.08	0.02	0.00	0.00	21.35
69-70	0.12	1.89	1.19	4.31	3.89	4.78	2.00	1.53	0.20	0.00	0.00	0.00	19.31
70-1	0.04	0.00	0.47	3.30	2.63	3.53	1.05	1.89	0.23	0.01	0.00	0.02	13.17
71-2	0.00	0.07	2.81	14.36	4.00	6.90	1.59	0.81	0.18	0.04	0.01	0.00	30.77
72-3	0.04	0.11	2.79	5.95	1.58	3.94	0.79	0.43	0.00	0.02	0.01	0.08	15.74
73-4	0.00	0.83	1.16	9.72	5.66	2.21	3.36	0.90	0.66	0.14	0.00	0.00	24.64
74-5	0.02	2.69	6.55	0.33	8.01	0.32	1.30	0.10	0.22	0.02	0.00	0.00	20.56
75-6	0.00	0.24	7.27	4.15	7.55	4.92	5.49	1.29	0.24	0.04	0.08	0.01	31.21
76-7	0.38	3.36	0.25	0.00	4.32	1.18	1.18	0.26	0.18	0.01	0.02	0.00	11.04
77-8	0.00	0.65	1.57	2.66	11.97	12.52	4.56	1.06	0.16	0.01	0.01	0.00	35.17
78-9	0.55	1.27	0.57	0.58	3.52	4.90	8.75	1.89	2.35	0.05	0.01	0.02	24.46
79-80	T	0.76	4.03	4.46	2.22	1.87	2.08	10.06	1.12	0.00	0.00	0.00	26.63
80-1	0.00	0.05	0.33	12.33	8.69	4.64	0.90	2.00	0.22	0.69	0.00	0.00	29.85
81-2	0.25	0.54	1.94	3.85	1.08	2.96	3.45	1.82	0.21	0.04	0.00	0.00	16.14
82-3	0.26	2.06	4.18	2.01	1.92	1.04	3.01	1.51	3.52	0.01	0.00	0.00	20.12
83-4	0.42	1.40	1.60	0.92	3.94	6.65	8.24	6.33	0.23	2.57	T	0.04	32.42
84-5	0.33	2.55	0.26	7.68	2.53	0.30	1.01	3.17	0.04	0.19	0.06	T	18.12
85-6	0.11	0.72	11.78	4.99	7.42	0.24	2.07	5.28	0.37	0.01	0.23	T	33.22
86-7	0.01	1.48	0.84	2.07	1.90	9.24	0.84	2.30	0.06	0.07	T	0.01	18.82
87-8	0.29	T	0.99	3.34	6.81	0.94	3.60	0.11	0.38	0.27	0.01	0.01	16.75
88-9	0.98	0.13	3.99	5.80	1.28	0.72	1.10	0.96	2.17	0.03	0.01	T	23.85
89-90	T	7.28	2.99	13.81	9.61	5.16	4.73	1.18	1.07	0.10	0.02	0.00	45.86
90-1	0.31	0.00	0.00	3.25	0.98	7.26	1.96	2.44	1.25	0.11	0.10	0.02	17.68
91-2	0.77	0.04	0.56	5.62	2.42	2.90	2.85	1.39	1.86	T	0.00	0.00	18.41
92-3	0.02	1.65	3.91	5.08	3.05	2.73	4.08	1.03	0.15	0.03	0.00	0.02	21.77
93-4	0.21	0.16	4.15	2.25	5.99	2.69	0.60	0.50	1.31	0.56	T	0.00	18.45
94-5	1.05	1.73	0.88	9.01	6.99	2.31	1.89	1.24	0.69	0.00	T	0.00	25.79
95-6	0.77	0.11	1.78	1.43	8.14	0.28	2.85	5.16	0.72	0.00	0.04	0.09	21.37
96-7	0.52	1.55	4.56	4.34	2.26	4.41	4.56	0.27	0.61	0.22	T	T	23.30
97-8	0.10	1.70	1.05	1.22	1.12	2.13	0.24	0.19	1.44	0.19	0.00	T	9.38
98-9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1899-1900	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Totals	10.07	47.02	133.65	250.39	241.65	274.34	153.31	92.18	35.67	7.22	0.82	0.81	1147.13
Mean Monthly.	0.21	0.96	2.72	5.11	4.93	5.56	3.13	1.88	0.72	0.14	0.02	0.02	23.41
Mean Seasonal.		3.89 Autumnal rains			13.60 Winter rains			5.73 Spring rains			0.18 Summer rains		

In this period of forty-nine years the normal seasonal rainfall has been 23.4 inches. In the period under consideration there have been fluctuations in seasonal rainfall from 7.4 in 1850-51, to 49.2 inches in 1861-2. The mean seasonal precipitation for the entire period is 23.4 inches, the mean for each month and for each season of the year being given in the table. The entire period may be subdivided into five classes: 1—extremely dry, 2—dry, 3—average, 4—wet, and 5—extremely wet years. This subdivision is an arbitrary one (as would be any subdivision whatever), and the following classification is made: Extremely dry years, less than 14 inches; dry years, from 14 inches to 19 inches; average years, from 19 inches to 28 inches; wet years, from 29 inches to 35 inches; and extremely wet years, over 35 inches of rainfall. Based on this classification we have the following: The seasons 1850-51, 62-3, 63-4, 70-71, 76-7, and 97-8 have been extremely dry, the mean monthly rainfall being as follows: September, 0.14; October, 0.74; November, 0.89; December, 1.62; January, 2.38; February, 1.76; March, 1.31; April, 1.12; May, 0.59; June, 0.03; July, 0.00; August, 0.04; or an annual mean rainfall for these years of 10.8 inches.

The eight seasons of 1851-2, 72-3, 81-2, 84-5, 86-7, 87-8, 90-91, 91-2 were dry years, with an annual rainfall between 14 and 19 inches, the mean monthly distribution for these years being: September, 0.38; October, 0.62; November, 1.20; December, 4.86; January, 2.31; February, 3.46; March, 3.02; April, 1.41; May, 0.50; June, 0.09; July, 0.02; August, 0.01; or an average mean rainfall of 17.39.

The twenty-three years, 1853-4, 54-5, 55-6, 56-7, 57-8, 58-9, 59-60, 60-61, 64-65, 65-6, 68-9, 69-70, 73-4, 74-5, 78-9, 79-80, 82-3, 88-9, 92-3, 93-4, 94-5, 95-6, 96-7 were years of between 19 and 28 inches, with a mean monthly distribution as follows: September, 0.23; Octo-

* Climate and Crops: California Section, U. S. Department of Agriculture, October, 1898.

† See a paper on "Importance of North Pacific Weather Stations," read by the author before the Science Association of the University of California, April 11, 1893.

ber, 1.00; November, 2.90; December, 4.08; January, 4.54; February, 3.08; March, 3.35; April, 1.98; May, 1.06; June, 0.11; July, 1.01; August, 0.01; or a mean seasonal rainfall of 22.37.

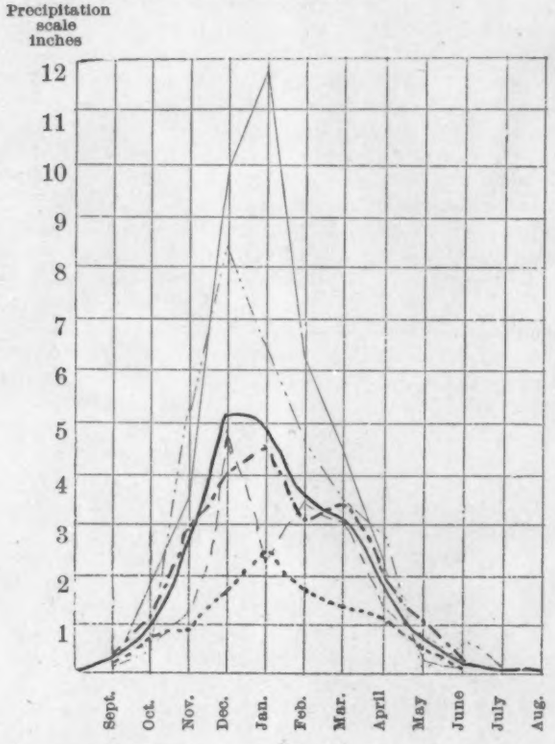
The seven years, 1849-50, 66-7, 71-2, 75-6, 80-81, 83-4, 85-6, were wet years, the extremes being 29 and 35 inches, with a mean monthly distribution as follows: September, 0.09; October, 0.81; November, 5.11; December, 8.30; January, 6.44; February, 4.62; March, 3.50; April, 2.65; May, 0.18; June, 0.46; July, 0.03; August, 0.01; or a mean seasonal rainfall of 32.21.

The five extremely wet years, having a rainfall in excess of 35 inches were: 1852-3, 61-2, 67-8, 77-8, 89-90. The mean monthly distribution of rainfall for three years was: September, 0.01; October, 1.79; November, 3.46; December, 9.98; January, 11.87; February, 6.27; March, 4.50; April, 2.13; May, 0.48; June, 0.08; July, 0.01; August, 0.01; the mean rainfall for these five extremely wet years being 40.89 inches.

The relation between each of these classes and of each class to the mean monthly distribution of rainfall for the entire period is shown on the following table:

Mean monthly distribution of rainfall for:	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Mean yearly rainfall for each group.
6 ex. dry years..	0.14	0.74	0.89	1.62	2.38	1.76	1.31	1.12	0.59	0.03	0.00	0.04	10.82
8 dry years.....	0.38	0.62	1.20	4.86	2.31	3.46	3.02	1.41	0.5	0.09	0.02	0.01	17.39
23 average years	0.23	1.00	2.90	4.08	4.54	3.08	3.35	1.98	1.06	0.11	0.01	0.01	22.37
7 wet years.....	0.09	0.81	5.11	8.30	6.44	4.62	3.50	2.65	0.18	0.46	0.03	0.01	32.21
5 extra wet years	0.01	1.79	3.46	9.98	11.87	6.27	4.50	2.13	0.48	0.08	0.01	0.01	40.89
Entire period..	0.21	0.96	2.72	5.11	4.93	3.56	3.13	1.88	0.72	0.14	0.02	0.02	23.41

These figures give the following diagram:



If these figures and the resulting curves yield any guide in forecasting seasons, we have the following: Both dry and extremely dry seasons are deficient in autumnal rainfall. In extremely dry years the greatest monthly deficiency occurs in December, and continues through the spring. In dry years the greatest deficiency falls in January, followed by a spring in which the departure from normal rainfall is light.

In years of average rainfall the maximum is in January, followed by a wet spring. In wet years the autumnal rainfall is heavy, followed by a maximum in December which continues above the normal through the rest of the winter and spring. In extremely wet years the maximum rainfall is in January, continuing well above the normal to April, and falling sharply below the normal in May.

These variations in the winter rainfall are primarily due to the changes in the position of the lines upon and along which the areas of low pressure originate and move in their course from the north Pacific into the interior of the continent. It therefore becomes important to know the causes and conditions controlling this shifting or restriction of the belt of rain distribution, for when these shall become known it will be reasonably possible to foretell whether a winter will be one of deficient, average, or excessive rainfall.

Since these storms approach from the west and move in from the north Pacific, all phenomena connected with their origin, course, and intensity, and even minute variations in these phenomena, become important. It is desirable, if possible, to ascertain where the moisture is evaporated which is precipitated on our shores, and whether there be changes in the locus of these areas; whether the variations in our seasonal rainfall be due to differences in air and sea temperatures, direction of winds, or in the position and intensity of barometric pressure over the north Pacific ocean, and the favorable and unfavorable combination of these and other factors. The agricultural products of California are becoming so important a factor in the world's markets that weather conditions affecting them are of great commercial value. It would not be possible to compute the value of a foreknowledge of what the general character of the season's rainfall was going to be. But it is entirely within the range of scientific investigation to determine in general what the conditions are, and to foretell within reasonable limits the probable amount of the seasonal rainfall, and this study merits the most thorough investigation and solution which science can devise.

Gas

ACETYLENE.*

BY PROF. VIVIAN B. LEWES, F. I. C., F. C. S.

II.

UP to the end of 1892 it was Willson only who made carbide on anything like a large scale, and nothing would ever have been heard of this material on a commercial scale had it not been that he, in attempting to get capital invested in his process, came across several men of sound, practical knowledge, whose business instincts led them to grasp the possibilities of carbide and acetylene. No sooner had these commercial possibilities been noised abroad than others began to try to make capital from them, but Wilson continued his experiments on a commercial scale throughout 1892 and 1893 and formed a company with works at Spray, N. C., utilizing 2,000 amperes at 25 volts. By this time the manufacture of carbide was well launched. The reports of Mr. Frank H. Mason, American Consul General at Frankfort, point out that the carbide industry, so far as central Europe is concerned, is now in a transition stage, and that the conditions of supply and price are likely to be modified by the enormous increase in production which is now being arranged for. In Germany, Austria and Switzerland arrangements are being made for the utilization of 35,000 horse-power, and elsewhere in Europe an additional 18,000 horse.power is to be utilized in the manufacture of carbide.

*Abstract of a series of four Cantor lectures delivered to the Society of Arts, London.

MANUFACTURE.

In the manufacture of calcic carbide in the electric furnace, lime and hard metallurgical coke of the highest possible degree of purity are employed. A good working mixture is 100 parts by weight of lime with 68 parts by weight of carbonaceous material, and about 1-8 pounds of this is used for each pound of carbide produced. It must not be forgotten in computing the cost of carbide that lime of sufficient purity for the purpose is not only costly but difficult to obtain in large quantities.

It is found that as the ignot of calcic carbide is formed in the furnace, although the ignot itself consists of pure crystalline calcic carbide, it is nearly always surrounded by a crust in which the carbide contains a certain proportion of imperfectly converted constituents. This gives a lower yield of acetylene than the carbide itself, and in breaking up and shipping the carbide in air tight drums, the worst of this crust is, as far as possible, picked out and rejected. It is perhaps misleading to state the amount made per electric horse-power, as a certain amount of loss is of necessity, entailed during breaking and packing. For instance, I have found that while the furnace return was, practically, 0.504 pound per kilowatt hour, this amount was reduced to 0.406 pound per kilowatt hour when ready for shipment. It will be sufficient for practical purposes to state that the cost of material, labor and wear and tear of plant independent of the power used in the electric furnace, but inclusive of packing, will amount to from $15 to $20 per ton, according to locality, which, of course, entirely governs the cost of the materials used, while the cost of the electrical horse-power necessary for the conversion of the material will entirely depend on whether it is obtained from steam, gas engines or water power, the latter, in Great Britain, costing nearly $20 per horse-power per year.

The two principal processes utilized in making calcic carbide by electric power are the ingot process and the tapping process. In the former the coke and lime are finely ground and carefully mixed in the right proportions to suit the chemical conditions involved. The arc is struck in a crucible and the powdered mixture is allowed to flow in and partially fill the crucible. An ingot gradually builds up from the bottom of the crucible, the carbon electrode being raised from time to time, automatically or by hand, to suit the diminution of resistance to the shortening of the arc by the raising ingot, the latter being surround by a mass of unreduced material which protects the crucible from the intense heat. When the ingot has been made and the crucible is full, the latter is withdrawn and another substituted. The process is not continuous, but a change of crucibles takes only two or three minutes under the best conditions, and occurs but once in every ten to fifteen hours. The essence of this process is that the coke and lime are only heated to the point of combination, and are not "boiled" after being formed. In the tapping process a fixed crucible lined with carbon is used. The electrode is nearly as big as the crucible, and a much higher current density is employed. Fine grinding is unnecessary, as combination probably only takes place after the fusion of the raw materials, which mix more or less as liquids. The carbide is heated to complete liquifaction and tapped at short intervals. There is no unreduced material and the process is considerably simplified, while less expensive plant is required; but, on the other hand, the output in carbide per electrical horse-power per day is considerably less than in the ingot process, and it is only more economical when power is comparatively cheap.

Carbide of calcium, as formed in the electric furnace at a temperature of 2,700° C., is a beautiful crystalline, semi-metallic looking solid, having a density of 2.22, and showing a fracture which is often shot with irridescent colors. It can be unaltered in dry air, but the smallest trace of moisture leads to the evolution of minute quantities of acetylene, and gives it a distinctive odor. It is infusible at temperatures up to 2,000° C., but can be fused in the electric arc. When heated to a temperature of 245° C., in a steam of chlorine gas it becomes incandescent, forming calcic chloride and liberating carbon, and it can also be made to burn in oxygen at a dull red heat, leaving behind a residue of calcic carbonate. Under the same conditions it becomes incandescent in the vapor of sulphur, yielding calcic sulphide and carbon disulphide, while the vapor of phosphorous will also unite with it at a red heat. It is a compound of calcium 62.5 per cent, and carbon, 37.5 per cent.

Acted upon by water calcic carbide is at once decomposed, yielding acetylene and calcic hydrate. Pure crystalline calcic carbide yields from 5.5 to 5.8 cubic feet of acetylene per pound at ordinary temperatures, but the carbide as sold commercially is a mixture of the pure crystalline material with the crust which, in the electric furnace, surrounds the ingot, and which, of course, yields less gas, the two being blended together to yield an average of 5 cubic feet of gas per pound of carbide under proper conditions of generation. But, as we shall see later, the volume of acetylene to be obtained depends very largely upon the form of apparatus to be used, some giving 5 cubic feet and others yielding but 3¾ cubic feet with the same barbide.

The purity of the carbide depends entirely upon the purity of the materials used in its manufacture, but although only the purest materials obtainable are now employed acetylene nearly always contains minute traces of hydrogen, ammonia, sulphuretted hydrogen, phosphoretted hydrogen, siliciureted hydrogen, nitrogen and oxygen, and sometimes carbon monoxide and dioxide.

M. Gerard has succeeded in extracting minute diamonds from the residues left after treating calcic carbide with water, the labor entailed in the separation of which may be estimated when it is stated that it was necessary to treat no less than between 700 and 900 pounds of carbide in order to obtain diamond material weighing 0.154 grain.

STORAGE.

There is no more risk in the storage of calcic carbide than there is in storing any other inert material, provided that it is packed dry and warm in hermetically sealed drums, so as to render it impossible for it to come in contact with water or moist air. The real risk is in the removal or redistribution of the material, as, after opening the drum, it may not be again properly closed, and if the drum be left open in this condition in the moist air of an ill-ventilated cellar it is quite possible for a slow generation of gas to take place, and for an explosive mixture to be formed by its accumulation. All carbide stores should be thoroughly well ventilated and above ground, and when this is the case all danger is practically done away with. For the carriage of carbide it is important that not only should the drums be air tight, but that they should be of sufficient strength to resist the rough usage incidental to the handling of a heavy product. Where tins are used they should always be protected by an exterior wood case.

(*To be continued.*)

Personal

MR. W. J. CLARK has accepted the position of general manager of the Foreign Department, with headquarters in New York, succeeding Mr. Mazonet, who for five years has held the general managership, and who has piloted it from its small beginnings to its present position as one of the foremost departments of the company. Mr. Mazonet now becomes managing director of the Mexican General Electric Company in the City of Mexico. Mr. Clark now has charge of all commercial relations between the General Electric Company and all countries outside the United States, and his wide experience in foreign commercial matters peculiarly fits him for his new position. He has traveled through Europe, as well as in the Central and South American countries, and his familiarity with foreign methods and manners will stand him in good stead. His book, "Commercial Cuba," recently published is already generally acknowledged to be the standard authority on Cuban commercial affairs.

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EDITORIAL.

"ALL THAT GLITTERS IS NOT GOLD."

Considerable space is devoted in this issue to a discussion of some phases of a problem that has been by far the most serious that has ever confronted electrical transmission interests in California, and now that the difficulties which it presented have for the nonce been averted or surmounted, as each case may be, and as its perplexities have worn themselves from the present into the past, it is fitting that the trying, if not racking, experiences of the season just closed should impress their lessons so strongly as to most effectually prevent for all time the recurrence of such conditions as have of late confronted most California transmissions with sternness. This problem is simply that of water supply, and its seriousness is due to the facts that water power plants can generate no power without water, and that precipitations from the reservoirs of Heaven are not controlled or even influenced in the slightest by the penalties inflicted upon transmission corporations for broken power contracts; corporations are proverbially soulless anyway, hence why should the gods bother about their well being? When the "oldest inhabitant" sagely shook his head and said: "That river war'n't bigger nor a tiny leetle creek in '51," the promoter of the new transmission enterprise branded him as a fossilized obstructionist or a degenerated prevaricator. But the summer of '98 proved him to be neither and the shake of his head was a forewarning which some have failed to heed to their own sorrow, as well as to the financial disappointment of their associates.

The leading article in this issue brings these facts out strongly, and its tenor is confirmed by the official record of precipitation in San Francisco appearing on another page. While the subject of Professor Baldwin's discussion is confined to southern California, it might have been more general in character, even to the extent of including practically all California transmissions, without shooting wide of the mark. So far as the writer is aware, the only large transmissions of great commercial importance in northern California that have not felt the pinch of the late drouth materially are those on the Yubas. The Nevada county plant forestalled the prospective shortage in water due to drouth and greatly increased business by increasing the head of water from 300 to 800 feet; the South Yuba company had augmented its output by the installation of the new power house at Auburn, thus enabling it to meet the emergency; but the North Yuba or Marysville plant alone holds the enviable record among transmissions in northern California of not only being prepared for every emergency without extra preparation but, at the same time, of having thousands of horse-power in water flowing to waste over its dam throughout the entire summer. It is a mystery where this water came from during a season of snowless mountains and thirsty ravines. The Kern river, too, has maintained considerably more than sufficient water to meet the demands of the Bakersfield transmission, but the Folsom and Fresno transmissions fell into bitter extremities—the former finding it necessary to install a 600 horse-power steam plant, and the latter finding its capacity reduced to one-third of the normal. Had the drouth occurred a year later Fresno would have been able to have withstood it, for the great impounding reservior it has been building for many months would then have been completed. Folsom finds the storage capacity of its great dam to be largely a myth because the dam impounds mud and slickens to the exclusion of water, and it has also found, it is said by those who are in a position to know, that the recently installed auxiliary steam plant produces electrical energy at a materially lower cost per kilowatt hour, investment and all fixed and operating charges considered, than does the transmission plant under similar conditions. But this should not be surprising when the enormous cost of water development, as well as the pioneering nature of the plant is considered.

The title of Prof. Baldwin's article is therefore unnecessarily restricted, and the unwelcome fact is that in the matter of shortness of water supply during 1898 each section of the Golden State may commisserate with the other. But as there are exceptions to the general order of drouth in the northern portion, other exceptions, notably the Southern California transmission, stand out prominently in southern California. The Redlands plant was the first to accept the inevitable order of things, which makes it imperative that southern California transmissions, as a class, should provide auxiliary generating stations as part of the original investment, and the sooner other transmissions whose contract loads exceed the delivered power available from the minimum flow of '98, follow the lead thus wisely made the more quickly will their recovery from the set-back of last year be effected. Auxiliary plants are inseparable to any transmission relying upon the water power of a stream of uncertain flow, and even though such auxiliaries lie idle fifty weeks in the year they are still indispensable, cost what they may. In truth, the cost of its auxiliary plant represents the penalty the transmission must pay for being dependent upon an uncertain water supply.

Whether or not an auxiliary plant is an essential adjunct to a water power transmission depends therefore upon the ratio existing between the minimum water supply and the contracted load it must carry at all hazards, but so great is the strife for business that it is not venturesome to state that the station manager will invariably load his plant, if possible, "up to the muzzle," as the saying is, without more than a passing thought, if that, bestowed to the consideration of that "possible dimly distant," or perhaps "too-remote-for-present-consideration" time when the cycle of the period of drouth shall again roll around and the plant will again be face to face with the stern reality that water power plants without water have only a junk value for the time being. Water power is not infallable; even the falls of the Willamette, the finest water power in the West, have been obliterated by the backing up of the waters of the Columbia river to the height of the water of the Willamette above the falls.

The four vital questions in Prof. Baldwin's article are most pertinent, and the discussion of them given brings out some fundamental points which are sometimes clothed in ambiguity, in a simple yet forcible way. It is feared, however, that serious exception will be taken to the estimates of cost given in Part III for the generation of power in southern California. Gas engine men, for instance, will maintain almost to a unit that the fuel consumed in gasoline engines will not cost to exceed one cent per horse-power-hour, while in steam engine practice it will be contended that $50 per horse-power is an unwarrantedly high estimate of cost for a 1200 horse-power plant, and that the item of labor and fuel for the same would be much nearer correct were it $65,000 instead of the $113,000 given. But it must be borne in mind that the assumptions are vaguely stated and that an equitable analysis of the figures given is therefore impossible. It is regretted that no approximation can be given of the cost of any large southern California power transmission.

The largest, best and most constant water power in southern California is that of the Southern California Power Company on the Santa Ana river, and trustworthy advices state that the minimum flow at its power house during the summer of '98 has been the equivalent of about 2000 horse-power delivered at Los Angeles continuously, *i. e.*, 24 hours per day. This places the southern California plant well towards the front rank of those Pacific Coast transmissions that have become noteworthy for the permanence and reliability of their sources of water supply.

But what is to come of the agitation opened up by the memorable drouth of 1898? Simply this: Better engineering, a deaf ear to the statements of promoters so far as they bear on matters of engineering fact; a more thorough investigation into the merits of steam plants and gas engines as producers of power in competition with water power transmission plants, and finally a gradual uplifting of the veil of enchantment which has caused the spirit of capital to look with favor upon every scheme for "the utilization of nature's forces" through the mountain stream, the water wheel, the dynamo and the electric transmission line. In reality there is no magic art in the legitimate electrical business, it stands on its own feet, from whence it must fight its own battles alone and unsupported, and the only question for it to decide is: Given a fitting market, wherein may be found the cheapest and most reliable means for delivering electrical energy therein. Three methods of doing this are or may be available: water power and transmission, steam and gas engines.

Throw off the fascinating spell that the beauties of electrical transmission has cast about you, come right down to hard, cold business principles and weigh the case presented by each locality solely on its merits without regard to predilections. Had this been done in the light of the knowledge of to-day and had there been followed the conclusions that now would have been drawn, the list of transmissions would not be quite so long as it is, and the value of the steam plant, particularly on tide water, would be by no means so lightly held. Great minds, too, have been at work for years on the development of the gas engine in large units and the fruits of their labors should soon be at hand. The efficiency of gas engines is far higher than that of any other form of prime mover, and the advent of its perfected type will be a boon of incalculable value to the electrical industry, for, come what may, electrical distribution will always hold a royal sway over all other methods.

GAS VS. ELECTRIC LIGHTING.

Gas and electric corporations meet at least on two common levels, namely, those of supplying artificial light and motive power, and leaving aside all questions of public preferences except that of lowest cost, it is inseresting to take up the thread of argument advanced by *The Gas World*, (Vol. XXIX, page 922,) which states a fair case in assuming first, that the public wants lights, and, second, that it wants this light at the lowest cost. It has been claimed by "electrical prophets," quotes our valued contemporary, that "within a very few years electrical energy will be generally sold at 1½d. per unit." or at the rate of 3 cents per kilowatt hour. We of the Pacific Coast know that in the far west the general or average cost of generation and delivery to the bus-bars will not begin to approach the low cost of 3 cents per kilowatt hour with present appliances, whether in steam or transmission practices, although in very few exceptional instances the low rate given has even been made yet lower.

Leaving this point, our contemporary then examines into the probabilities of electricity "at 1½d. per unit," securing all the lighting business. Electrical energy at this price means that 250 candle-hours can be obtained for 3 cents, assuming an efficiency for incandescent electric lamps of 4 watts per candle, or if an efficiency of 3 watts per candle be assumed, 333 candle-hours in incandescent electric lighting would cost 3 cents. It is claimed that an efficiency of 20 to 25 candles per cubic foot of gas have been attained in the newest incandescent gas burners, or Welsbach mantels. Prof. Lewes, however, states that 17

candles per cubic foot is a good workable figure, according to which 19.6 cubic feet of gas will be required to give the 333 candle-hours obtained from one kilowatt of electrical energy. Throwing in the odd 0.4 cubic foot for gas consumed by the by-pass and the consumption of an even 20 cubic feet will be obtained, In England the average cost of gas is 2s. 6d. per thousand cubic feet, and the cost of the gas light will be 0.6d. (1.2 cents) against 1½d. (3 cents) for electricity, in other words, electric will still be two and one-half times as expensive as gas light according to the price of gas in England

This very rational mode of bringing out a comparative estimate of costs between lighting by gas mantels and by incandescent electric lamps grows in interest the further it is carried, and to localize it, in San Francisco 3.6-watt lamps are ordinarily used, while about the lowest rate at which electrical energy can be obtained is 7 cents per kilowatt hour. On this basis 1000 watt-hours of current will deliver 277 candle-hours of light, which, as it costs 7 cents, means that one cent's worth of current will give 39.6 candle-hours. Turning now to the other side, illuminating gas costs $1.75 in San Francisco, or for one cent a trifle over 5.7 cubic feet of gas will be delivered. Applying this gas to a Welsbach mantel, which Prof. Lewes states to have a lighting efficiency of 17 candles per cubic foot of gas, it is found that the cent's worth of gas will give 96.9 candle-hours against the 39.6 candle-hours which are obtainable from electricity by incandescent lighting. To meet $1.75 gas on the common level of equal cost per candle-hour, electricity will have to be sold at the rate of about 2.7 cents per kilowatt-hour. With gas at $1 per thousand the electrical equivalent will be 1.6 cents per kilowatt hour.

If electric lighting interests will persist in ranking gas as an enemy it is for their well-being that they should not underestimate the fighting qualities of their quondam antagonist; if they are wise they will be quick to recognize the extraordinary efficiency of gas for lighting and heating purposes, and will, as these columns have so often urged, hasten to make an ally of so valuable an agency. Gas and electric lighting are sister sciences—not inherently antagonistic industries.

Passing Comment

An Editorial Review of Current Events and Comtemporary Publications.

TO STANLEY BELONGS THE CREDIT.

Prof. Baldwin makes a valuable contribution to the history of electrical transmissions when he states in the leading article of this issue, in reference to the San Antonio Light and Power Company of Pomona, Cal., which is the pioneer 10,000-volt transmission of America, that "electrically it was far more successful than the highest hope of the Westinghouse company which made the installation. It is due to Mr. William Stanley, of the Stanley Electric Manufacturing Company of Pittsfield, Mass,, to say that he approved the plan which I presented to him, and agreed to install the plant if the Westinghouse and Thompson-Houston Company refused to do so. This proposition of Mr. Stanley's led both companies to reconsider their refusal to undertake it, and the plant was put in under the direction of Mr. L. B. Stilwell, now of the Niagara Company."

It has always been supposed that the bold use of 10,000 volts on the famous Pomona plant was due to the progressiveness of the Westinghouse company, but the glory it has worn so long loses its lustre in the light of Prof. Baldwin's statement. That it bears the imprint of authenticity is not to be doubted, because of Prof. Baldwin's worthy name and the fact that he has been the president of the San Antonio Light and Power Company from its inception.

* * *

THE VALUE OF A WATER POWER.

Apropos of the subject matter of the leading editorial of this issue, which might with equal propriety have been under the above caption, it is of advantage to note that a current number of the *Mining and Scientific Press* says:

The value of a water power depends upon a variety of elements; numerous conditions may reduce its value. The essential points to be considered are as follows: Quantity of water during a dry year; uniformity of flow during the year, considering the storage capacity, natural and artificial; head of fall; conditions which fix the expense of building dam and canal, and flowage of land; conditions which affect the cost of foundations for buildings; geological conditions which determine the permanency of the fall; freight charges for fuel, supplies, raw materials and finished product; how much low-pressure steam can be used for heating purposes, and whether exhaust steam can be used for those purposes; if water is needed for other purposes than power, and in what quantities; the greater uniformity of speed with steam than with water power. The value of a variable power is usually very little if its variation is very great, unless it is to be supplemented by a steam plant. It is of value then only when the cost per horse-power for the double plant is less than the cost of steam power under the same conditions for a permanent power. The value of a developed water power is usually as follows: If the power can be run cheaper than steam the value is that of the power, plus the cost of plant, less depreciation. If it cannot be run as cheaply as steam, considering its cost, etc., the value of the power itself is nothing except in connection with possibilities in the direction of electricity or compressed air; but the value of the plant is such a sum as could be paid for it new, which would bring the total cost of running down to the cost of steam power, less depreciation. That is, it is worth just what can be got out of the plant, and no more.

GRAPHITE FROM ACETYENE.

The *Gas World*, London, states that Herr Bergmann finds that he can make beautiful graphite powder in quantity by oxdizing acetylene under pressure:

$$C_2H_2 + O = C_2 + H_2O.$$

He exposes acetylene along with peroxide of hydrogen to a temperature of 150° C., under a pressure of five atmospheres:

$$C_2H_2 + H_2O = 2H_2O + 2C.$$

The graphite may be filtered off. The same treatment applied to carbide of calcium results in a mixture of lime and graphite which can be separated by dissolving the lime in an acid and filtering.

"Your San Gabriel article is most interesting and accurate."—H. P. REED, Los Angeles, Cal.

Transportation

ROTARY CONVERTERS IN RAILWAY WORK.*

BY LOUIS BELL, PH. D.

IT is the purpose of this article to explain what the rotary converter is, how it operates in practice, and under what circumstances it becomes economically available for railway work. For the general purpose of electric power transmission we have at present to depend on alternating currents, while nearly all the railway work of the world is by continuous current motors. Hence, to render transmitted energy available for the purpose in hand, it must be represented by continuous current derived in some practical and economical way from the alternating current. In the first place, one can utilize the alternating current in a suitable motor and thence drive a continuous current generator; second, one can rectify the current by a commutator driven by a synchronous motor; and finally, the alternating current can be changed to continuous current by the rotary converter.

ALTERNATE CURRENT CONVERSION.

The first method involves the driving of two machines and adding the losses therein, a process obviously not of the highest efficiency, although sometimes advisable. On the other hand, to rectify alternating current by a commutator, while very highly efficient, brings in certain grave inherent difficulties which have never yet been successfully surmounted on any considerable scale. Chief among these difficulties is destructive sparking, due to the fact that it is practically impossible to so time the revolution of the commutator that the brushes shall pass from one segment to the next, thus rectifying the current, at the moment when the alternating current is passing through zero, and when there is, simultaneously, no difference of potential between the segments.

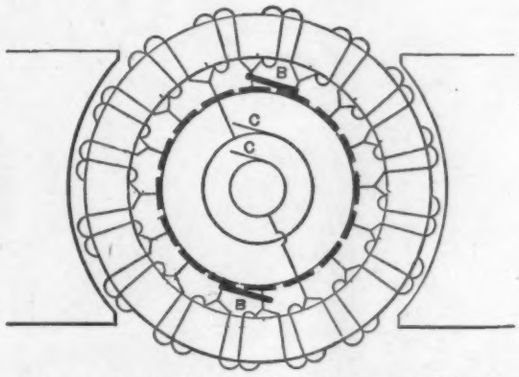


FIGURE 1.—CONNECTIONS OF SINGLE-PHASE ROTARY CONVERTER.

On a small scale one can work a commutator so that both current and potential difference will be small when the brushes pass to the next segment, and so the sparking will be small, but the moment one deals with large currents and considerable voltages, that is, with large outputs, the sparking becomes destructive, particularly if the load changes rapidly. Thus, while synchronous commutators have proved fairly successful in small units, say of five to twenty kilowatts, for charging storage batteries and the like, they give very little promise of success on the scale required for railway work.

Now the rotary converter is an apparatus for cummuting alternating current under the same conditions that exist in the armature of an ordinary continuous current generator. We must remember that, fundamentally, all armatures generate alternating current, and that the sole function of the ordinary commutator is to so reverse the connections of the armature with respect to the external circuit that the current delivered to the latter shall be uni-directional. This commutation is done piecemeal, as it were, each individual armature coil being reversed in connection as it passes under the brush, so that the reversal deals with only a small portion of the total voltage—a few volts or even a fraction of a volt. We all know what trouble from sparking ensues when the voltage between commutator segments is too great.

Now the commutator neither knows nor cares what is the source of the current with which it deals—whether it is being generated in the armature or fifty miles away—so long as it is being delivered to it in the systematic way for which it was designed. Therefore, if just such alternating current is delivered to the armature as the latter was designed to deliver to the commutator, the process of commutation will go on in the regular way. And this is the essence of the rotary converter; it is a dynamo adapted to receive from an external source and to turn over to its commutator just such alternating current as it would necessarily generate if driven by its own engine.

Figure 1 gives a clear idea of the connections which would be found in a simple single-phase rotary converter. The armature there shown in diagram is a Gramme ring with sixteen armature coils and the same number of commutator segments. In addition to the commutator the armature is provided with two collecting rings *C C*, permanently connected to two diametrically opposite points of the armature winding. Now if the fields pertaining to this armature were excited and the armature were driven by a pulley, it would evidently produce continuous current if an external circuit were connected to the regular brushes *B B*. Similarly if these brushes were disconnected and the circuit were connected to the brushes bearing on the collecting rings *C C*, we should get an alternating current, for there would be no commutation and the current in each half of the armature would be reversed at each half revolution, that is, at each pole. If the speed of the armature were 1500 revolutions per minute, there would be in the resulting alternating current 3000 reversals per minute, amounting to twenty-five complete cycles per second, which is the frequency employed in the great Niagara plant.

SINGLE-PHASE ROTARIES.

We may thus consider that every continuous current armature generates within its coils an alternating current which has a definite frequency dependent on the number of poles and the revolutions per minute. We may commute this current or not, as we please, but it is always there and ready to be used if we put on collecting rings and take it out. The higher the speed and the greater the number of poles, the greater the intrinsic frequency of the machine. With four poles and 1500 revolutions per minute, the frequency would be fifty cycles, and in general for any machine it is, in cycles per second

$$\frac{\text{Number of poles} \times \text{r. p. m.}}{120.}$$

Now suppose that we send into the armature of Figure 1, through the rings *C C*, an alternating current of twenty-five cycles per second, after spinning the armature up to 1500 revolutions per minute. By so doing we have converted the machine into a synchronous alternating motor, and it will fall into step with the generator and run steadily along like any other alternating motor. Its speed will be 1500 revolutions per minute, and the current in its armature will reverse precisely as if it were being generated therein instead of arriving from the outside. The fields in this case would have to be excited from some external source.

PRINCIPLE OF OPERATION.

While the motor is running in this wise, what will happen if we let down the brushes *B B* and close a circuit upon them? There are now two paths open for the alternating current sent through *C*. One of them is via the armature windings, and against the counter electromotive force of the field to the other collecting ring, just as before the brushes *B B* were connected. The other is through the windings to a brush *B*, and through the external circuit to the other brush, thence through another bit of the armature winding to the opposite collecting ring.

Evidently the current will divide itself between these two paths, both being available. But the portion, which takes the path through *B B*, is passed through the commutator in the regular

* Abstract from the *Street Railway Review*, September, 1898.

way, and emerges as continuous current in the external circuit just as if it were generated in the armature itself. For the alternating impulses sent into the armature are timed with respect to the position of the windings just as if they were generated there and are kept in this relation by the fact that the armature is kept in synchronism by its action as a motor. The energy required merely to keep up this rotation is very small, and, as in other motors, the counter electromotive force automatically keeps the motor current down to the modest amount necessary to supply this energy. All the rest of the current which can be supplied to the machine up to the limit of endurance of the armature conductors may be taken from the commutator as continuous current. In fact, an armature used in this way will stand rather more current without overheating than could safely be generated in it. For the current which passes on to the line through the brushes *B B* is not compelled to traverse the whole of the armature windings, but only such parts of them as are between the brushes and the commutator segments to which the rings *C C* are connected. In fact, there will be a moment at which the current can pass directly from *C C* to *B B*, and on the average the path of the commuted current is much shorter than if the same armature were used to generate it. From what precedes it at once becomes a natural inference that any continuous current dynamo can be worked as a rotary converter if properly connected. This, within limits, is true, and the first rotary converters were formed by adding collecting rings to ordinary dynamos.

We have seen, however, that every dynamo is intrinsically fitted to generate current of a particular frequency at its regular speed, and unless supplied with alternating current of that frequency the speed would have to be changed in using it as a rotary converter. In point of fact most dynamos have too few poles to be thus converted unless at a much higher speed or lower frequency than is desirable.

So far we have dealt only with the converter for single phase current, which is used only to a limited extent. Single phase synchronous motors are not self-starting, so there would be trouble in getting such a rotary converter up to speed, and, besides, there are excellent reasons for using in preference the polyphase systems for power transmission work. The polyphase rotary converters operate on precisely the same principles just explained and differ only in their connections. The machine shown in Figure 1 could be converted into a three-phase rotary converter by applying three collecting rings and connecting them to commutator segments as nearly as possible 120 degrees apart. It would operate in just the same way as before, but would be able to start itself like any other three-phase synchronous motor running light. Similarly we could make a quarter-phase converter by tapping the winding at four points 90 degrees apart and applying four collecting rings to be connected to the four wires of the quarter-phase system. Both these forms, the connections of which are shown, diagrammatically, in Figures 2 and 3, give shorter average paths for the commuted current than the single phase form, and hence on the whole give rather better outputs.

POLYPHASE ROTARY CONVERTERS.

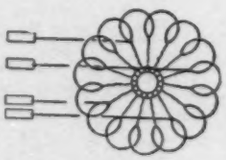


FIG. 2.—TWO-PHASE ROTARY.

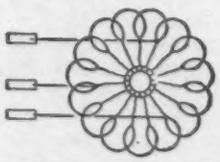


FIG. 3.—THREE-PHASE ROTARY

Thus far we have said nothing about the question of voltage in rotary converters. The voltage applied can obviously be varied in almost any way, but it is equally obvious that if the commutator is designed for, say, 500 volts, it will give trouble as in an ordinary generator, if forced much above that point. In fact, the commutator of a rotary converter is designed like that of any other machine for a particular voltage, and since the current sent into the armature should be the same as that which could be generated in it, for any given continuous voltage the alternating pressure applied should be that which the machine would give if run as an alternating generator. This is considerably less than the continuous current voltage, since the mean effective voltage by which alternating current is rated is not the crest of the wave which, however, is the voltage, approximately, coinciding with that of the continuous current given by the same machine. Now in a single phase rotary converter the alternating current leads are taken out 180 degrees apart, and in a quarter-phase there are two pairs of wires separated by the same amount so that in these cases, if the machine give a sine wave, the effective alternating voltage would be $\frac{1}{\sqrt{2}}$ times the corresponding continuous voltage; *i. e.*: about seven-tenths as great. In the three-phase form the corresponding alternating voltage is still further reduced by the fact that while the continuous current brushes are 180 degrees apart, the alternating leads are only 120 degrees apart. The ratio in this case is $\frac{\sqrt{3}}{2\sqrt{2}}$ that is, about six-tenths.

VOLTAGE RELATIONS.

Hence, if one wishes to derive from a rotary converter 500 volts for railway service, the applied alternating voltage will have to be about 300 to 500 volts. This, of course, means that in transmitting power for this purpose, step-down transformers must always be used. The exact ratio between the alternating and continuous pressures is subject to some slight variations due to the alternating wave shape and various minor causes, and one cannot in any way change either voltage without affecting the other. This is sometimes an inconvenience, for it makes the continuous current voltage subject to any inductive disturbances on the alternating side of the line.

Since the voltage at the commutator is not generated by the armature directly, it is not directly affected by the field strength as in ordinary dynamos, hence compound winding does not affect a rotary converter in the ordinary sense. Indirectly, however, it can be made to serve a useful purpose by reacting upon the alternating side of the line, and thus varying the applied voltage very materially. It is a well known fact that the voltage at the motor end of a line driving a synchronous alternating motor can be varied within wide limits by changing the field strength of the motor, and this holds true of the rotary converter, which, as we have seen, acts as a motor.

Another curious feature of the machine is the fact that the polarity of the continuous current derived from it depends on the way the alternating current is flowing when the brushes are put in circuit. If they catch a positive impulse the current is in one direction, if a negative impulse, in the other. As they are, however, so they stay, and it is not a difficult matter to get the polarity right.

In their general behavior, rotary converters are strikingly like the best continuous current generators. They operate beautifully in parallel on either side or both sides, spark very little, show very little armature reaction, stand overloads well, and really leave little to be desired in point of efficient and smooth operation. Their efficiency is, in fact, rather higher than if they were used as generators, for the reasons already pointed out, and their use gives a thoroughly practical method of deriving continuous from alternating currents. Only in rare cases is their chief weakness—the complete interdependence of the two circuits—of any moment. Occasionally, when the transmission circuit is very long and must be kept clear of complicated line reactions, or when the frequency used is inconveniently high or low, it is best to fall back on the motor generator. Rotary converters can be built for any frequency, but a large machine for high frequency forces an extreme multipolar construction to keep down the peripheral speed, and this means a very complicated commutator. On the other hand, a very low frequency would compel a bipolar construction when a multipolar machine would be cheaper and better. Under ordinary conditions the rotary converter is at its best at from twenty to forty cycles per second.

GENERAL CHARACTERISTICS.

When the motor generator is used it is a few per cent. less efficient than a rotary converter and somewhat more costly, but,

counting in the cost and loss of efficiency in the transformers needed to supply low voltage to the latter, the difference is less than would be at first supposed.

Having thus looked over the general properties of the rotary converter, we may pass to the conditions attending its economical use for railway purposes. In its relation to the working line it must be considered merely as a continuous current generator. So far as it is concerned with the trolley line proper, a sub-station with rotary converters is precisely the same thing as an independent generating station, with the same arrangements for feeding the trolley line and the same relation to the general conditions of operation. By employing such a sub-station one merely substitutes current delivered over high voltage feeders from a distant point for current generated on the spot. In general, the use of rotary transformers is for one of two purposes — to utilize water power situated at a point distant from the railway line, or to feed a long line from a single steam-driven station. These are two entirely distinct propositions so far as the economics of the matter is concerned.

ROTARIES IN RAILWAY SERVICE.

The first involves the comparative cost of water power and steam power delivered at a given point, the second the relative cost of steam power generated in stations of different sizes and with different load factors. The margin for profit is generally greater in the former case than in the latter, and instances of the successful use of rotary converters are in the former correspondingly more numerous.

There are at present numerous examples of railways driven by transmitted water power through the agency of rotary converters. The first instance of this kind was the Portland, Ore., road, which for the past four or five years has been operated by a thirteen-mile transmission from the falls of the Willamette. Then there are the two great plants of this kind at Buffalo and at Minneapolis and a considerable list of smaller installations. It is not too much to say that all of these have been successful and economical, for they have substituted comparatively cheap water power for rather dear steam power. The question here is merely the general problem of electrical power transmission from waterfalls.

When we come to the other case — the distribution of power from a central steam-driven generating station to sub-stations scattered over a city or along an extended railway line, the conditions are very different. Here there is no chance for wholesale saving in the cost of power, but there is the opportunity for substituting one large station for several of less capacity and dispensing with a very large amount of feeder copper. Ordinarily, when large amounts of power must be furnished to outlying districts, feeder copper is installed to meet the growing demand until finally the amount becomes very burdensome, and then a new station is built. As an alternative a sub-station with rotary converters and a high voltage feeding line may be installed. In the case of a long interurban line the feeder copper is a burden from the very start, and the question of separate stations versus transmission to sub-stations is at once pertinent. The advantages of this procedure may be very material. In the first place, all the power generation is done in a single large station, which can be located at the most advantageous point along the line, so that one gains the saving always found in working on a large scale. Second, by this concentration the central station gains in having a load factor somewhat better than any one of several separate stations could have, while the load factor of a rotary transformer station can never lead to any gross inefficiency.

IN RE STEAM PLANTS.

All this is very nice, but there are a few other things to be remembered. The cost of the rotary converters, transformers, line and generator and station capacity to operate the sub-station system will generally be greater than the cost of separate stations — much greater if these stations are few in number and of fairly large capacity. Usually, too, the total labor account will be increased rather than diminished, since there will always have to be at least a small force at each sub-station and added force at the main station, besides the care of the transmission line, an item which it is by no means safe to neglect.

And finally, it must not be forgotten that for every kilowatt delivered from the terminals of the rotary converters, at least 1¼ kilowatts must be generated at the central station, and usually more than this. In other words, one cannot reasonably expect to get from the transmission system — line, transformers, and rotary converter — an all-day efficiency higher than about 80 per cent., and it will oftener be 75 per cent. than 80. If one were working under conditions of maximum economy, 80 per cent. could certainly be surpassed, but railway work does not furnish these conditions.

The cost of the transmission and depreciation thereon add still other charges against the system, and the upshot of the matter is that unless the central station can generate power fully thirty per cent. cheaper than it can be generated in several separate stations, distribution to rotary converter stations will not pay. Let us now proceed to investigate the chances of meeting this condition.

The first thing to be looked into is the variation of the cost of power with the size of the generating station and with the load factor. This is, of course, variable in each case, depending on the relative costs of fuel, labor, etc., but under particular assumptions as to these items for any special locality, the variation we are seeking can be readily deduced. The curves of Figure 4 give a typical case, and the relation between the different values indicated will not vary materially within the limits usually found in practice.

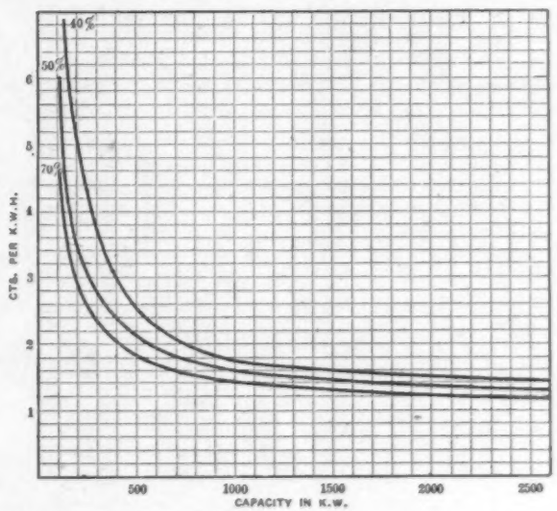


FIGURE 4.—DIAGRAM SHOWING COST IN CENTS OF KILOWATT-HOURS.

Figure 4 shows the approximate cost of power in cents per kilowatt hour for stations of 100 to 2500 kilowatts capacity, working at load factors of 40, 50 and 70 per cent. The latter figure is only reached in large city plants operating a great many cars. Fifty per cent. is a common load factor for well-handled systems of moderate size, and 40 per cent. is by no means rare. The curves are based on coal at three dollars per ton and steam and electric plants of average character, neither exceptionally good nor unusually bad. The absolute costs are of course only approximations, but are well borne out by the results reached in practice. They include interest and depreciation, two important items generally left out of the published costs of power, and hence appear high to the uninitiated.

THE ECONOMIC FEATURES.

Bearing in mind the fact that there is generally no difficulty in getting a good load factor in plants of 1000 kilowatts or more, let us look over these curves with relation to the use of rotary converter stations. From 1000 kilowatts upward the cost of power falls very slowly indeed. We have just seen that to justify the

use of rotary converters a central generating plant must generate power much more cheaply than several independent stations, since to make up for losses in transmission and extra cost of plant, one must count on producing at least 1⅓ kilowatts for each kilowatt delivered from the converter stations. It is therefore apparent that with sub-stations as large as 1000 kilowatts there is small chance for economy in using sub-stations, unless the total output is very great indeed. The central plant would have to run considerably over 10,000 kilowatts before it could pay to employ sub-stations of that size on street railway service. It is conceivable that if one were operating a long interurban road with heavy traffic and at high speed, such an arrangement might pay in virtue of improved load factor, but even in this case the long distances of transmission would tend to more than offset the gain. Data from actual plants tend to show, too, that above a few thousand kilowatts capacity, there is practically no material decrease in cost of power. There is strong reason to believe, therefore, that it can seldom or never pay to operate a large urban system from a single plant with rotary converter sub-stations. In fact, such a scheme of operation should be turned down on the score of putting too many eggs in one basket, if for no other reason. It may readily happen, however, that at some remote point of such a system a sub-station may be profitably utilized, employing, perhaps, rotary converters of a type that can be utilized later as generators when it becomes desirable in the growth of traffic to erect an independent station, or to link several stations together by a transmission system.

When the total output required must be divided into scattered units of only a few hundred kilowatts each, the advantages of transmission become more important. If, for example, one is operating a considerable interurban line requiring, say, a total capacity of 1000 kilowatts, and the question arises between two 500 kilowatts stations and a 1000 kilowatts station with a 500 kilowatts sub-station, considerable discrimination is required. At 70 per cent. load factor in a 1000 kilowatts station the cost per Figure 4 will be about 1.4 cent per kilowatt hour. In a 500 kilowatts plant at the same load factor the cost would be about 1.8 cent. This in itself is too small a margin to justify rotary converters. If, however, the 500 kilowatts plant cannot be assured of a load factor higher than 50 per cent., the cost will be, say, 2.15 cents, while the larger plant remains at 70 per cent., thus shifting the balance to the other side of the ledger. The question of economy, therefore, hinges under such conditions on the relative load factor of the whole system and of its parts. Few data are available on this particular item, since nearly all plants aggregating 1000 kilowatts, or even several times as much, are operated from a single station. In the few systems operated from several power stations the load factor does not vary greatly between station and station, but the stations are mostly so large that little variation would be expected. With an aggregate power as low as 1000 kilowatts, the use of sub-stations is evidently on debatable ground. On the other hand, with an aggregate power of 500 kilowatts such as might exist on an interurban line, the curves make it very evident that transmission to a sub-station would pay.

In general, one may safely say that unless a line requires for independent stations in the neighborhood of 500 kilowatts each, there is a strong probability that transmission from a single station will pay. With outputs above that point, sub-station work will very often be found to be uneconomical. The dividing line between the two cases appears to lie under ordinary conditions somewhere between 250 and 500 kilowatts for each station, where only two stations are concerned. It must not be supposed, however, that one can settle the case once and for all by installing a number of small sub-stations, for with extreme subdivision one comes at once into competition with boosting and other modifications of ordinary feeding systems.

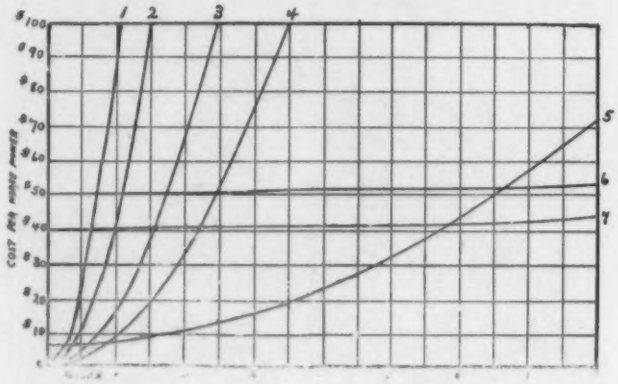
Under present conditions the rotary converter finds the most important use in the utilization of water power for railway purposes, and in this field its importance must not be lightly estimated. In some interurban work it is likely to find a legitimate and important use even when operated from a steam plant. In heavy city and surburban work its value is, to say the least, very problematical so far as general distribution is concerned, although it is not unlikely to prove a useful adjunct. Its chief weakness is in the fact that, like other moving machinery, it requires attention, and furthermore, it cannot be applied without a very material loss of energy. Skillfully used, however, it is a most valuable addition to the resources of modern engineering.

Electro-Economics

RELATIVE COSTS OF CONDUCTING SYSTEMS.*

BY CHARLES F. SCOTT.

ACCOMPANYING this are curves showing the general relation between the first costs of different systems for conducting power from the generator to the consumer. These curves are, of course, only approximate; the cost of conductors has been taken at about 15 cents a pound for copper, without reference to insulation; no allowance has been made for



the middle wire of the three-wire system, and the cost of apparatus depends largely upon the size of the units used.

The cost for copper for 220-volt transmission and 10 per cent loss is seen to be $21 per horse-power for one mile and $85 for two miles. The cost is half as great when the loss is 20 per cent, but the distance for a given cost is increased only 40 per cent.

The cost for 2000-volt transmission includes a constant representing the lower transformers. The curve does not include the secondary conductors for the transformers. If the distance be short the cost is small. The lower curve for rotaries includes the cost of transformers, rotary and 10,000 volt circuit. The upper curve includes the direct current distribution circuits, assumed to have an average length of one-third of a mile, if the voltage is 220, and three-quarters of a mile if the voltage is 500—the loss being 10 per cent.

It is seen that the direct current transmission is cheaper to install than the 2000-volt alternating current with transformers, if the distance be less than about a quarter of a mile (the voltage being 220), or two-thirds of a mile (the voltage being 500). The cost of copper for 2000 volts becomes excessive when the distance exceeds a few miles; for greater distances a higher voltage should be used.

The curves representing the rotary sub-stations show a high first cost. This can be justified only by economics in operation. A comparison between these curves and the 2000-volt curve for the alternating current throughout shows the advantage of an alternating current distribution over that by direct current through sub-stations. Besides the reduction in first cost, the attendance at sub-stations is abolished, and the efficiency is increased.

"Let me congratulate you on your 'jim dandy' article on the San Gabriel transmission. You did yourself proud that time," writes a well known electro-technical literateur of New York City.

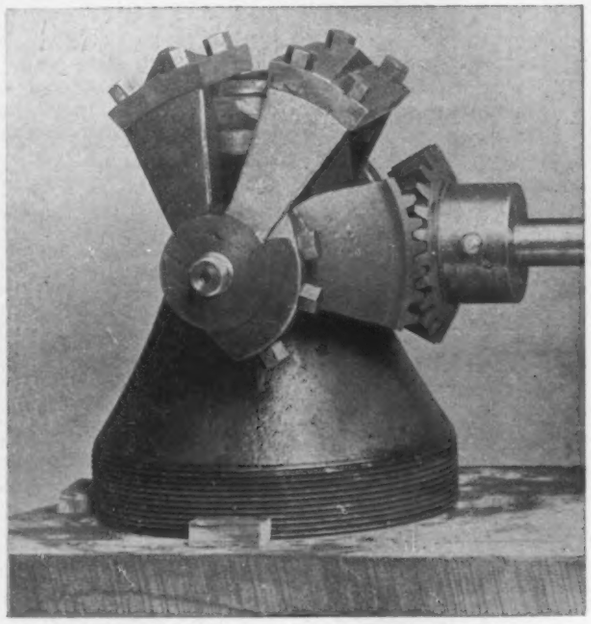
*From *The Engineering Magazine*, Volume XVI, page 267.

Hydraulics

CUT-OFF NOZZLES AT THE ASPEN POWER HOUSE.

BY C. E. DOOLITTLE.

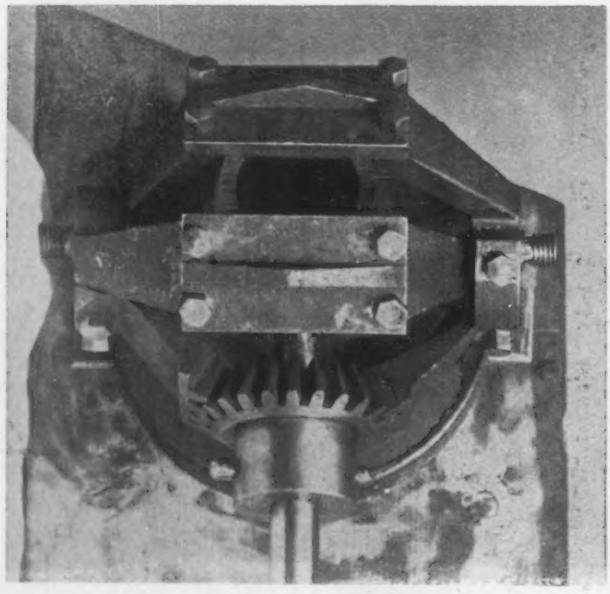
WATER for the pipe line of the Roaring Fork Electric Light and Power Company's plant, at Aspen, Colo., is taken from a reservoir at the lower end of the company's flume. The load consists largely of mine hoists and is, of course, exceedingly



A DUPLEX CUT-OFF NOZZLE.—SIDE VIEW.

variable. As dependence must be placed in the supply of water in the reservoir to carry the run through many a cold winter night, it is necessary that the efficiency of the wheels be high at any load.

The Pelton wheels used are set in pairs and there are two nozzles for each wheel. The use of the valve or cut-off nozzle here illustrated, together with a device for operating the valves in succession, gives a much higher efficiency under variable load than is obtained in any other plant using reaction wheels of which the writer knows.



A DUPLEX CUT-OFF HOOD.—TOP VIEW.

The advantage of this form of valve over the hood valve which was used in the Aspen plant referred to some five years ago and which has since been used to a considerable extent, is that the direction is always tangent to the wheel.

Industrial

In Responding to Advertisements in this Publication, please mention "The Journal of Electricity."

ENCLOSED ARC LAMPS OF NEW DESIGNS.

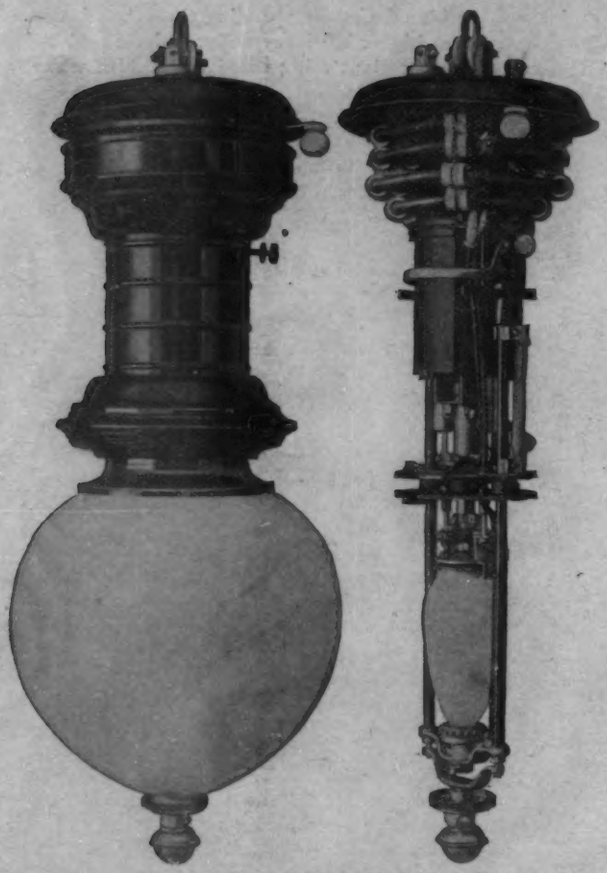
A PERFECTED form of carbon feed arc lamp for direct connection across 220-volt mains is being placed on the market by the General Electric Company. It operates with 120 volts at the arc, takes a normal current of 2.5 amperes, and, with one trimming, has a life of from 130 to 150 hours, requiring no attention during that time. The carbons are so proportioned that the upper carbon at the end of the run may be placed in the lower carbon holder for the next run. The light is of less volume and more violet in color than standard 110-volt lamps, but the advantages of a 220-volt lamp capable of independent operation, sometimes compensates for the diminution of light as compared with the General Electric 5-ampere power-circuit lamp for use two in series across 220-volt mains. A variable resistance at the top of the mechanism allows the use of the lamp on circuits of from 210 to 250 volts and disconnection from the circuit is effected by a quick break switch applied to each lamp. The 220-volt lamp is weatherproof and may be used without a hood, being especially suitable for lighting vestibules, doorways, window fronts, etc. It may be used with the closed outside globe as shown in the illustration or with the single globe and flared reflector. The casings are of several designs, the standard weatherproof casing being finished in black enamel.

220-VOLT LAMPS.

Following next in the line of enclosed arc lamps developed by the General Electric Company, a subtantial, simple, and efficient power-circuit lamp has been perfected for use two in series on 220-volt circuits, or five in series on 500-volt circuits. In outward appearance it resembles the alternating and direct-current carbon-fed enclosed arc lamps of the same company, and is manufactured in both single and double globe types. To conform to insurance regulations covering the use of arc lamps on high voltage circuits, a safe, positive and reliable cutout is incorporated in the lamp, together with an extra set of resistance coils. Should the carbons stick, or the lamp for any reason fail to operate, the cut out sends the current through these subsidiary resistance coils instead of through the carbons, without detriment to the lamp. The efficiency of this cut out has been demonstrated by cutting out lamps in circuit and allowing them to remain cut out for several consecutive hours, without resultant injury either to coils or lamp.

POWER-CIRCUIT LAMPS.

The mechanism is simple and made up of but few parts. The carbon is fed by a double cam clutch, smooth and positive in action. An adjustable resistance in the upper part of the lamp allows it to be employed two in series on circuits of 200 to 240 volts, or five in series on circuits of 500 to 600 volts. With one 12-inch positive, and one 5½-inch negative carbon, it burns after one trimming for from 130 to 150 hours, and after the run, the remainder of the positive carbon, as in the 220-volt lamp, can be used in the lower carbon for a second run of equal duration. The current required is five amperes. The lamp is furnished with the same globe lowering device that has been fitted to over 30,000 General Electric enclosed arc lamps, and which permits the globe to be lowered gently by merely turning a milled thumb screw at



POWER CIRCUIT ARC LAMP.

the side of the casing. The globe holder is locked automatically by a single upward movement of the globe holder. Power-circuit lamps are furnished in weatherproof black or brass casings, that shown in the illustration being the weather-proof casing.

MARINE ARC LAMP

MARINE LAMPS.

Adequate electric illumination of wharves, docks, warehouses, dry docks, shipyards, with their adjacent iron working shops, and the holds of vessels, while loading or discharging, demands a type of lamp somewhat different from that used for street or store lighting. It must be strong, compact and durable, or it will not withstand the hard usage which such service will naturally give it; it should give a large volume of clear, white light, which will not dazzle the eyes of the workmen nor throw heavy shadows in already obscure corners; it should require little attention, and be so simple that it can be attended by an average lamp trimmer; lastly, it should require trimming not daily, but only at long intervals.

The lamp which, perhaps, best meets these requirements is the marine enclosed arc lamp, also manufactured by the General Electric Company. It has been made the object of special design to adapt it to marine usage on shipboard or land. The mechanism is compact, simple and reliable, and is protected from injury or the effects of the weather by a stout metal casing. It is only necessary to renew the upper or long carbon once in 100 to 150 hours, the lower carbon, after the first run, being, as in the previous instances, the unburnt remainder of the upper carbon. With open arc lamps, it was necessary to renew the carbons every day. The outer globe shown as of clear glass in the illustration, is cylindrical in shape, of thick glass and protected from injury by a heavy wire guard. The globe can be lowered by a half turn of the thumb screw at the side, and when pushed back in position is automatically and securely locked. The lamp is only twenty-eight inches long. It can be carried from place to place if necessary, and hung by the metal ring at the top to any convenient hook, or may be permanently fixed in place like an ordinary arc lamp. The lamp can be used on a 110-volt circuit and can be adjusted for 4, 4.5, or 5 amperes, the latter being the standard.

Many of these marine lamps have been installed in locations such as those mentioned above, and have in every case given very satisfactory service.

MOVED TO MORE COMMODIOUS QUARTERS.

The Pacific Arc Lamp Company has moved from 23 Stevenson street to 149-155 Fremont street, San Francisco, where it has secured much more commodious quarters and greatly improved facilities for the manufacture of the Pacific Arc Lamp. The company has also secured large showrooms for exhibiting the "Northern" electric motors and dynamos, and the well known "Hardy" incandescent lamps, a large stock of each of which will be carried in San Francisco.

In addition the company has a large force of excellent workmen and are in position to do all kinds of repairing.

Mr. John Martin, of the Pacific Coast agency of the Stanley Electric Manufacturing Company, has been appointed agent of the Pittsburg Reduction Company, for the sale of aluminum for purposes of electrical construction in the west.

TABLE OF CONTENTS.

Illustrated articles are designated by an asterisk (*); Editorials by a dagger (†); Passing Comment by a double dagger (‡), and Industrial by a section mark (§).

Electro-Economics

*Relative Costs of Conducting Systems, by Charles F. Scott..... 18

Gas

Acetylene—II, by Prof. Vivian B. Lewes, F. I. C., F. C. S..... 10

Graphite from Acetylene..... 14

Hydraulics

*Cut-Off Nozzles at the Aspen Power House, by C. E. Doolittle..... 19

Illumination

§*Enclosed Arc Lamps of New Design..... 19

†Gas vs. Electric Lighting..... 13

Personal

..... 11

Transmission

†"All That Glitters is Not Gold"..... 13

*Rainfall in San Francisco from 1849 to 1898, by Marsden Manson, C. E., Ph. D..... 9

‡To Stanley Belongs the Credit..... 14

‡The Value of a Water Power..... 14

Water Powers in Southern California, by C. G. Baldwin..... 5

Transportation

*Rotary Converters in Railway Work, by Louis Bell, Ph. D..... 15